Developing Algorithm Components for GPM Snowfall Retrievals

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Introduction

The goal is to develop/refine algorithm components that can be used for snowfall detection and retrievals using GMI (and other microwave radiometers in the constellation) observations. Specifically, we are working on the following components: (1) a snow-rain separation algorithm using ground-based observations, (2) a database of ice scattering properties and approximation methods for snowflakes, (3) an empirical snowfall detection/retrieval algorithm guided by radar observations, and (4) a snow cloud vs. brightness temperature database for snowfall retrievals over ocean.

Snow-Rain Separation

A snow-rain parameterization is developed using data:
Land: NCEP ADP Operational Global Surface Observations, 1997-2007
Ocean: International Comprehensive Ocean-Atmosphere Data Set (ICOADS), 1995-2007
Upper Air: Integrated Global Radiosonde Archive (IGRA)

Input variables:
- Air temperature (2 m)
- Humidity (2 m)
- Low-level (0 - 500 m) lapse rate
- Surface skin temperature
- Land or ocean

Output:
Probability of Solid Precipitation (Sims and Liu, 2015 JHM)
An equation version now available

Scattering Database for Aggregates

Aggregate snowflakes have been created with their dimension-mass relation constrained by consensus of observations. Their scattering properties have been calculated using DDA and scattering table is archived on the web. With the addition of table to the earlier table for crystal type particles, we now have the scattering table for full range of ice/snow particles, with types of "rounded", "oblate" and "prolate" aggregates. (Liu, 2008; Nowell et al., 2013; Honeyager et al., 2015). They are used to study the difference of triple-freq radar signature between convective and stratiform clouds (Yin et al., 2017).
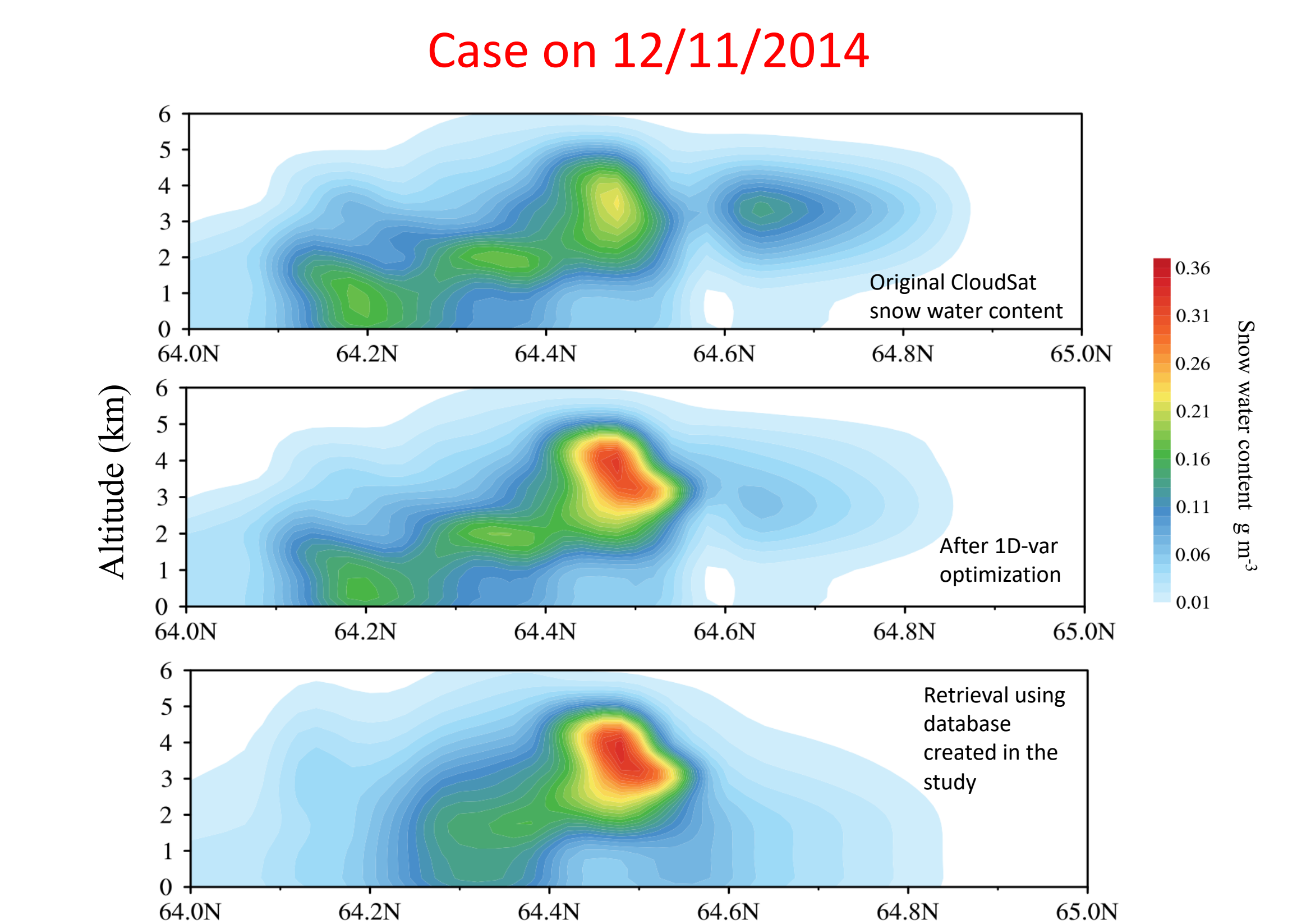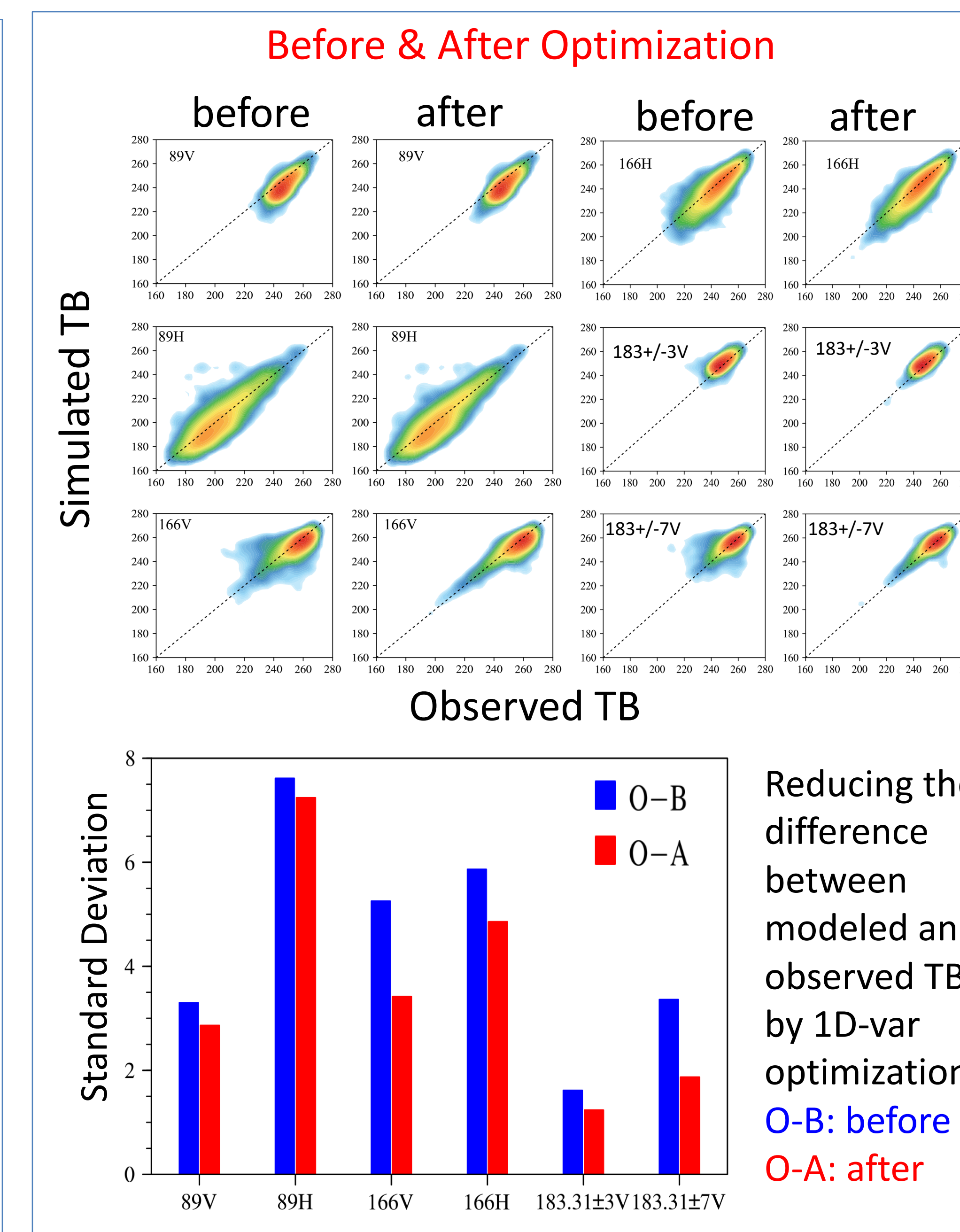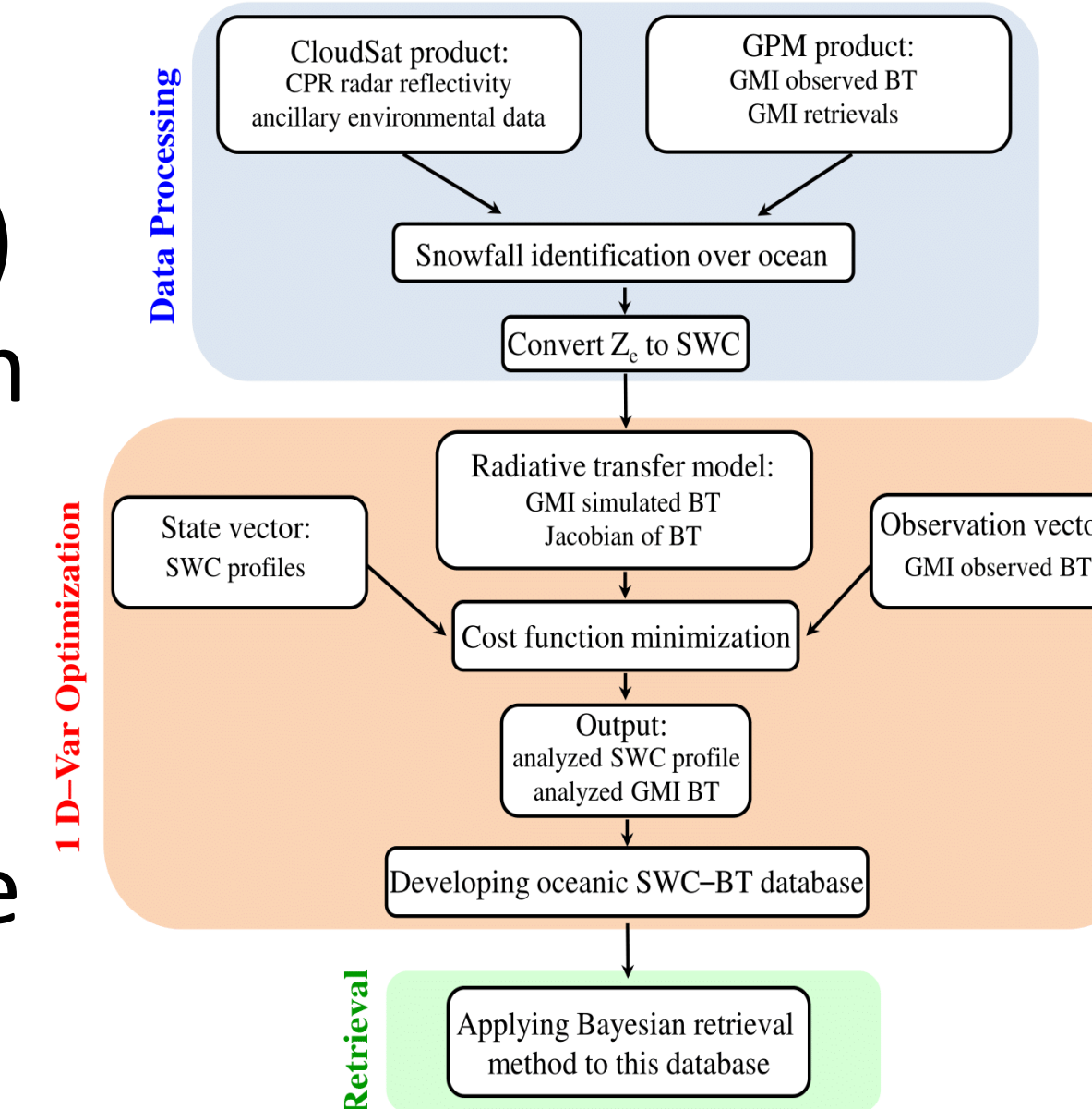
Conclusions

- Improving a pre-screening scheme to separate conditions of snow/rain, using ground-based environmental variables – T, q, Γ, etc.
- Continuing to the enhance snow scattering table and apply it to study ice microphysics
- Developed an empirical radiometer snowfall retrieval algorithm guided by radar observations
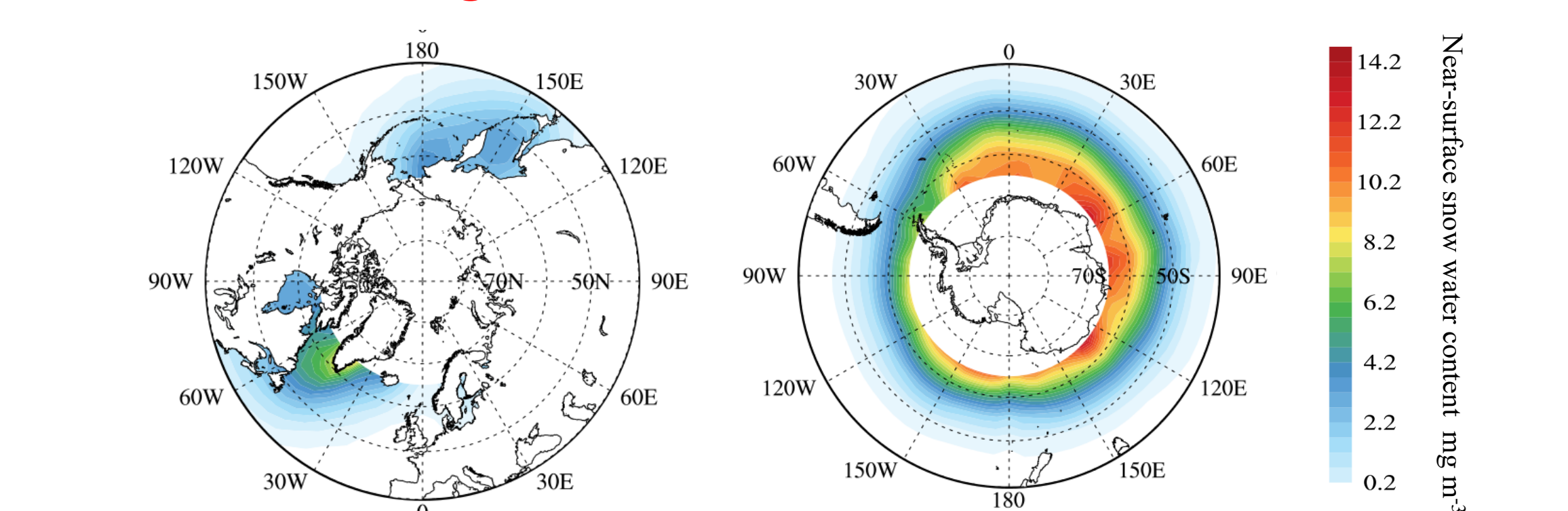- Developed a snow cloud – TB database for snow retrieval over ocean

Development of Snow Cloud – Brightness Temperature Database

Approach: Over ocean, surface and atmospheric radiation can be better simulated. We explore the feasibility to build a physically consistent database relating brightness temperatures to snow cloud properties. The approach uses merged CloudSat, GPM, and reanalysis data.

It starts with snow water content (SWC) profiles derived from CloudSat CPR, uses a radiative transfer model and a 1D-Var optimization scheme to obtain a snow cloud properties – GMI TB database, which can be used for SWC/snowfall rate retrievals (Yin&Liu, 2017).
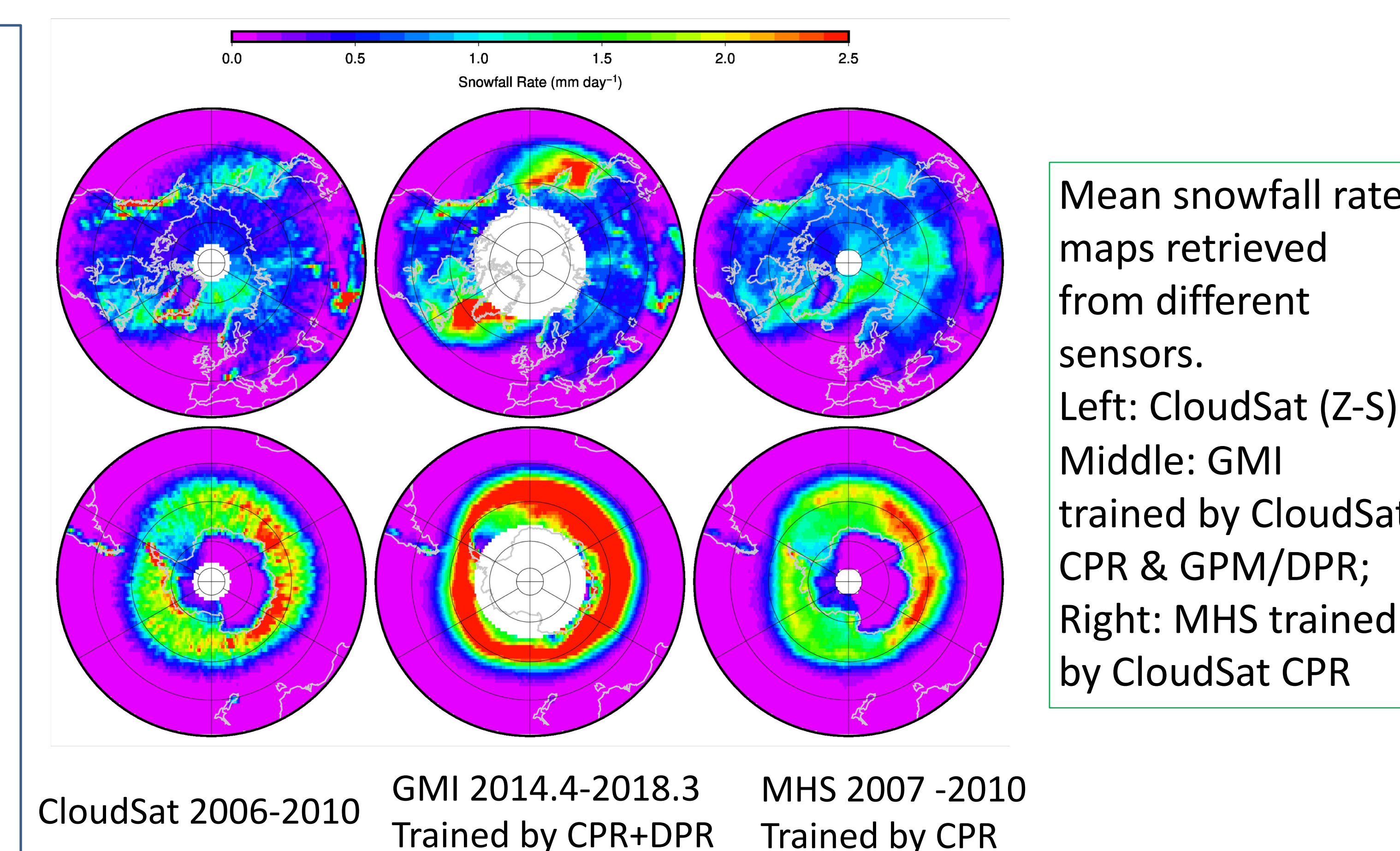

Before & After Optimization

Reducing the difference between modeled and observed TBs by 1D-var optimization
O-B: before
O-A: after

Case on 12/11/2014

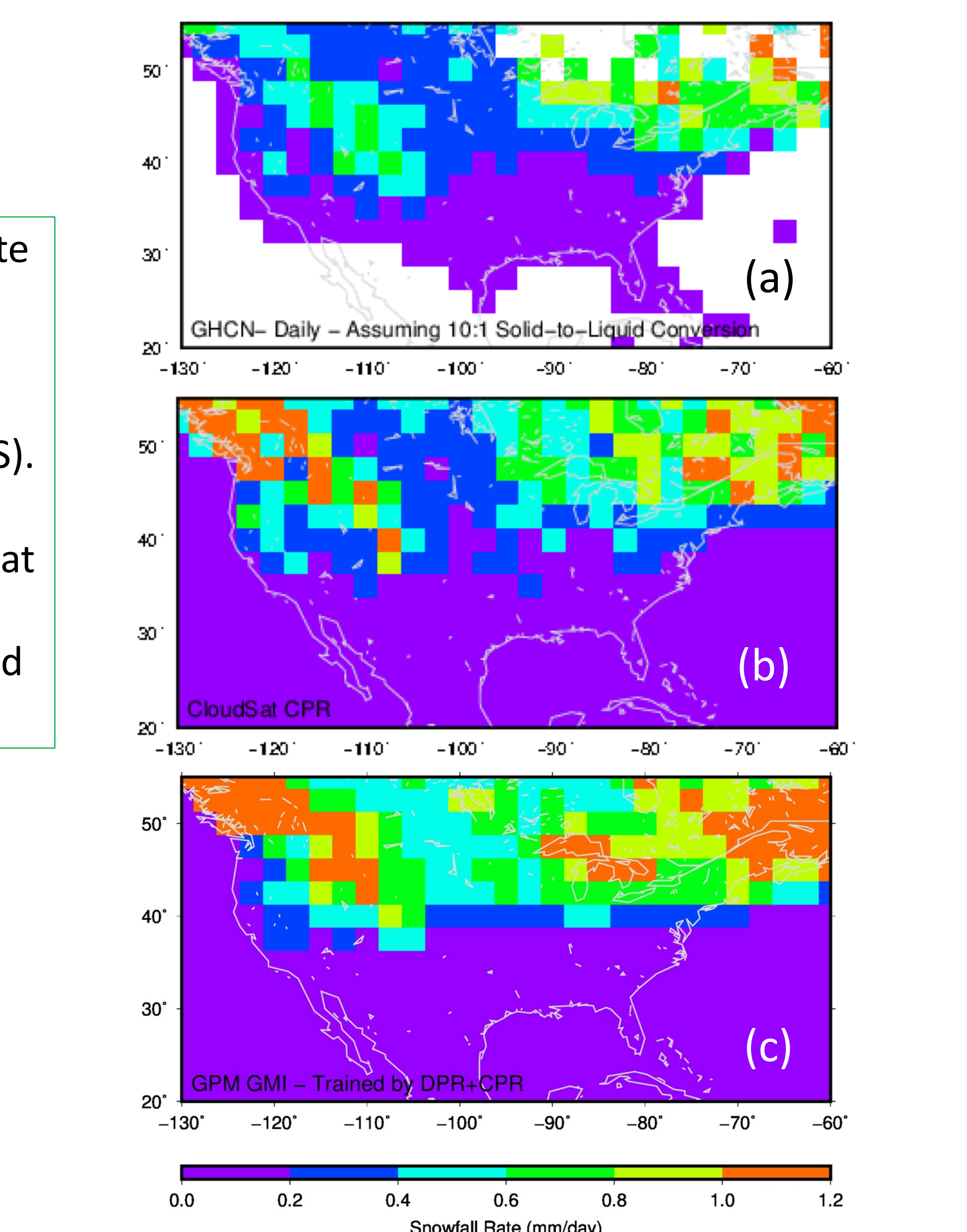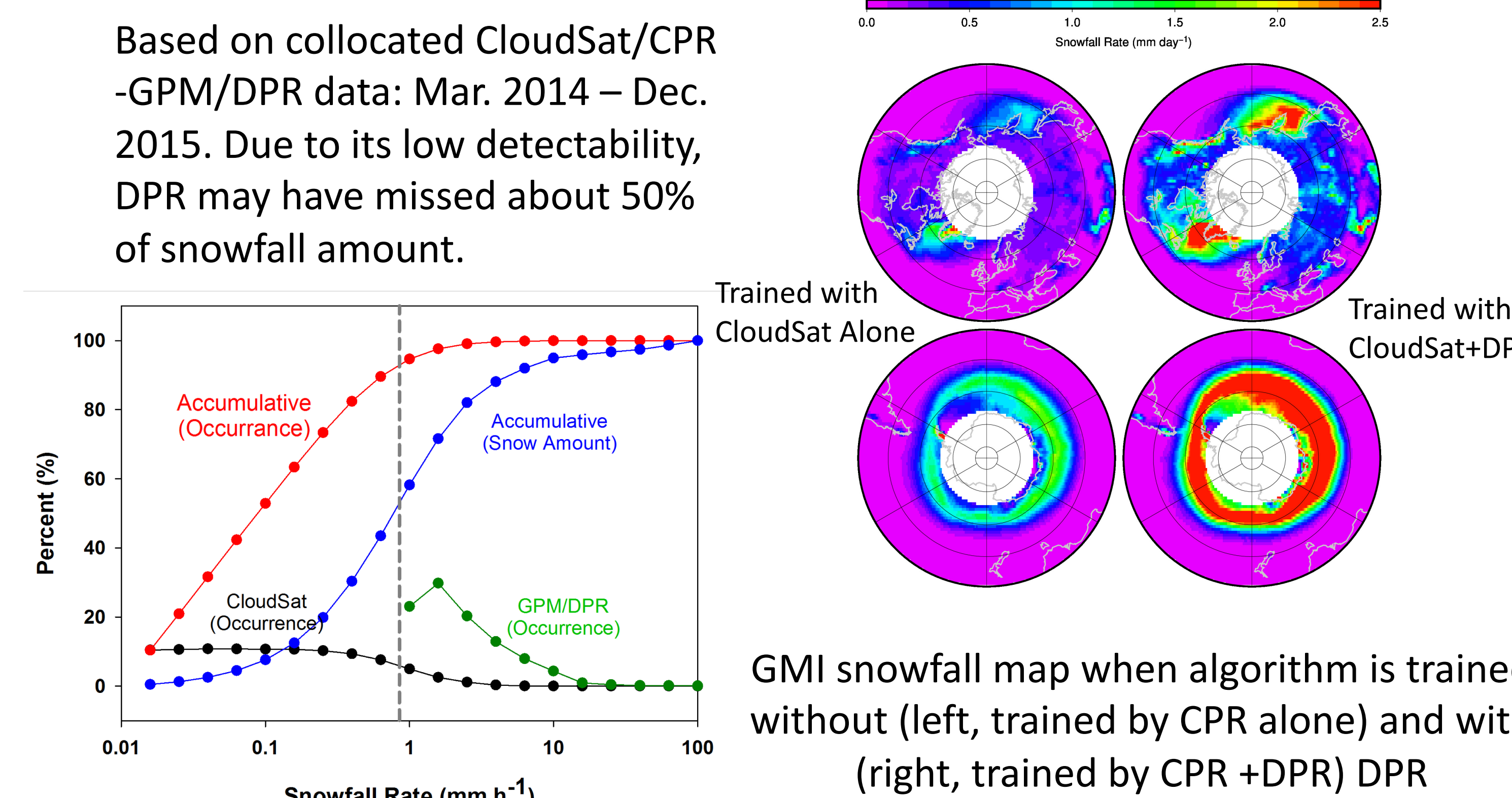GMI-retrieved global SWC at near-surface level for 2015

Empirical Snowfall Detection and Retrieval

Method: Over land, snowfall detection/retrieval is based on an empirical algorithm – trained using coincident MW radiometer and radar (DPR+CPR, as truth) data pairs. From radar reflectivity, we first we estimate snowfall rate based on modeled nonspherical ice backscattering, then train (high-frequency) passive microwave observations in 3D brightness temperature EOF-space to give snowfall probability and snowfall rate (Seo and Liu, 2013)

CloudSat 2006-2010   GMI 2014.4-2018.3 Trained by CPR+DPR   MHS 2007 -2010 Trained by CPR

Mean snowfall rate maps retrieved from different sensors.
Left: CloudSat (Z-S).
Middle: GMI trained by CloudSat CPR & GPM/DPR;
Right: MHS trained by CloudSat CPR

Use combined CloudSat/CPR vs. GPM/DPR as "truth": DPR (Ku or Ka) has a minimum detection of about 13 dBZ, missing most of snowfall events, while CloudSat CPR has clear attenuations for heavy snowfall. Combined DPR-CPR data are used as "truth" in the GPM GMI empirical algorithm. Z-S relations for DPR/CPR are derived from nonspherical ice scattering database with assumed size distributions.

Based on collocated CloudSat/CPR -GPM/DPR data: Mar. 2014 – Dec. 2015. Due to its low detectability, DPR may have missed about 50% of snowfall amount.

GMI snowfall map when algorithm is trained without (left, trained by CPR alone) and with (right, trained by CPR +DPR) DPR

(a) GHCND + Canada Station observed climatology – multiple years
(b) CloudSat – near surface, 2006 – 2010.
(c) GMI – 2014.4-2018.3, trained by CloudSat/CPR + GPM/DPR
o Similar pattern – therefore, GMI is able to catch the snowfall signature
o Different magnitude – need more study for "truth" data, Z (radar) to S (snowfall) conversion.